Carbon Sequestration in Tropical Tree Crop Systems – especially in Rubber Plantations (Hevea brasiliensis)

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Carbon Sequestration in Tropical Tree Crop Systems – especially in Rubber Plantations (*Hevea brasiliensis*)

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Outline

• Introduction
• Case Study from Ghana
• Research conducted
• REDD+ and rubber plantations
• Examples of rubber plantation projects
• Summary

Langkawi, Malaysia - Photo: R. Kongsager 2009
Introduction

- Land-use and land-cover change has contributed about 33% of global carbon emissions over the past 150 years.
- However the current relative contribution has declined to 10-13% annually (Houghton et al. 2012).
- A growing interest in lowering the emissions of greenhouse gases from different types of land-use.
- Compared to other tropical agricultural crops.
- Potential to increase sustainable development if projects are implemented in the right way.
- REDD+ (payment scheme).

- Question: Are rubber plantations a good climate change mitigation option?
Carbon Pools in Tree Systems

WHERE DOES CARBON GO?
CARBON STORAGE IN A GREAT LAKES FOREST

LEAVES 1%
TRUNK & BRANCHES 40%
WOODY DEBRIS 1%

SOIL RESPIRATION 2.2 tons of carbon / acre yearly

NET PHOTOSYNTHESIS 2.9 tons of carbon / acre yearly

CARBON STORED 0.7 tons of carbon / acre yearly

TOTAL ECOSYSTEM CARBON 80 tons / acre

SOIL ORGANIC MATTER 45%
Case Study

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Figure 6: Map of ARC-Kade. 1: Primary forest (> 100 years). 2: Orange plantation (15 years). 3: Oil palm plantation (16 years). 4: Oil palm plantation (23 years). 5: Oil palm plantation (7 years) 6: Rubber plantation (44 years). 7: Cacao plantation (21 years). 8: Rubber plantation (12 years) 25 km south of Kade. Red lines indicate transects, white circles indicate primary forest plots, and red squares in 6 and 8 indicate rubber plots.
Climate

Note: compared to Malaysia: temp the same, but precipitation is around 1000mm higher in Malaysia

Fig. 2 Climate diagram, ARC-Kade, 1980-2010. Annual averages: precipitation 1,425 mm; temperature 26 °C. Data for 1984, 2005, 2006 and 2007 are incomplete and not included (data provided by Dr S. Adjei-Nsiah 2011)
## Plantations Measured

### Table 1 Specifications of the plantation measurements

<table>
<thead>
<tr>
<th>Variable measured</th>
<th>Cocoa</th>
<th>Oil palm</th>
<th>Rubber</th>
<th>Orange</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number of trees/stems measured</td>
<td>Diameter at breast height</td>
<td>Height</td>
<td>Diameter at breast height 442 (178 from 1967 and 264 from 1999)</td>
<td>Basal area 108 (94 alive and 14 dead/missing)</td>
</tr>
<tr>
<td>Number of plantations measured</td>
<td>246</td>
<td>360 (120 from each year)</td>
<td>4 and 44 years old (planted in 1967)</td>
<td>25 years old (planted in 1986)</td>
</tr>
<tr>
<td>Age</td>
<td>21 years old (planted in 1990). Shade trees 40 years old.</td>
<td>7 years old (planted in 2004), 16 years old (planted in 1995) and 23 years old (planted in 1988)</td>
<td>12 years old (planted in 1999) and 44 years old (planted in 1967).</td>
<td>20.71 ha</td>
</tr>
<tr>
<td>Total size of area</td>
<td>13.9 ha</td>
<td>50.04 ha (2004), 13.9 ha (1995), and 30.58 ha (1988)</td>
<td>55.6 ha (1999) and 38.92 ha (1967)</td>
<td>266.93 stands/ha</td>
</tr>
<tr>
<td>Planting density</td>
<td>1,097.39 stands/ha</td>
<td>144 stands/ha</td>
<td>Unknown</td>
<td>Citrus sinensis (Late valencia)</td>
</tr>
<tr>
<td>Species</td>
<td>Theobroma cacao</td>
<td>Elaeis guineensis (Tenera)</td>
<td>Hevea brasiliensis</td>
<td>The plantation was measured in equivalent rows.</td>
</tr>
<tr>
<td>Type of plot</td>
<td>Since distinct rows of cocoa trees were absent, circular plots with a radius of 20 m were chosen.</td>
<td>Since no palms were missing in the rows, the oil palm plantations were measured in rows equivalent to two acres (0.4047 ha) as transects through each plantation.</td>
<td>Because of incomplete rows, we measured in 60×60 m squared plots instead of only equivalent rows. Trees were missing since no replanting took place if a tree died, as the older trees would shade the younger trees too much.</td>
<td>The plantation was measured in equivalent rows.</td>
</tr>
<tr>
<td>Plots</td>
<td>5 plots of 314.15 m² = 0.16 ha = 4% of the total population.</td>
<td>1 transect of 120 trees in each plantation = 0.81 ha = 6% (2004), 20% (1995) and 9% (1988) of the total population.</td>
<td>2 plots of 3,600 m² (in both plantations) = 0.72 ha = 4.5% (1999) and 16% (1967) of the total population.</td>
<td>6 rows of 18 trees = 108 trees = 0.405 ha = 6.7% of the total population.</td>
</tr>
</tbody>
</table>
Results

In comparison was the carbon content in the unmanaged natural forest (> 100 years) at the research station measured to be 130.2 tC/ha (permanent content – no rotation)

<table>
<thead>
<tr>
<th>Type</th>
<th>Age [years]</th>
<th>Aboveground [tC/ha]</th>
<th>Accumulation [tC/ha/year]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cocoa</td>
<td>21</td>
<td>65.0</td>
<td>3.1</td>
</tr>
<tr>
<td>Oil Palm</td>
<td>7</td>
<td>21.7</td>
<td>3.1</td>
</tr>
<tr>
<td>Oil palm</td>
<td>16</td>
<td>28.0</td>
<td>1.8</td>
</tr>
<tr>
<td>Oil Palm</td>
<td>23</td>
<td>45.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Rubber</td>
<td>12</td>
<td>61.5</td>
<td>5.1</td>
</tr>
<tr>
<td>Rubber</td>
<td>44</td>
<td>213.6</td>
<td>4.9</td>
</tr>
<tr>
<td>Orange</td>
<td>25</td>
<td>76.3</td>
<td>3.1</td>
</tr>
</tbody>
</table>

Time-averaged carbon content (30 year rotation)

- Cocoa: 46
- Oil Palm: 30
- Oil palm: 75
- Orange: 46
Rubber plantation 44 years, ARC-Kade, Ghana - Photo: J. Napier 2011
## Other Case Studies

<table>
<thead>
<tr>
<th>Average carbon content in aboveground biomass</th>
<th>Comment</th>
<th>Location</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>75 ton C/ha with a 30 year rotation period</td>
<td>Ghana</td>
<td>Kongsager et al. 2012</td>
<td></td>
</tr>
<tr>
<td>90 ton C/ha permanent agroforest</td>
<td>Indonesia</td>
<td>Palm et al. 2005</td>
<td></td>
</tr>
<tr>
<td>50 ton C/ha intensively managed</td>
<td>Indonesia</td>
<td>Palm et al. 2005</td>
<td></td>
</tr>
<tr>
<td>93 ton C/ha 38-year chronosequence</td>
<td>China</td>
<td>Yang et al. 2005</td>
<td></td>
</tr>
<tr>
<td>76 ton C/ha 14-year-old stands</td>
<td>Ghana</td>
<td>Wauters et al. 2008</td>
<td></td>
</tr>
<tr>
<td>42 ton C/ha 14-year-old stands</td>
<td>Brazil</td>
<td>Wauters et al. 2008</td>
<td></td>
</tr>
</tbody>
</table>

Average carbon content of natural forests for all tropics: 94 tC/ha (Houghton 2005)

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## Carbon in Oil Palm

<table>
<thead>
<tr>
<th>Average carbon content in aboveground biomass</th>
<th>Comment</th>
<th>Location</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 ton C/ha</td>
<td>with a 30 year rotation period</td>
<td>Ghana</td>
<td>Kongsager et al. 2012</td>
</tr>
<tr>
<td>48 ton C/ha</td>
<td>rotation times of 25 years</td>
<td>Indonesia</td>
<td>Palm et al. 2005</td>
</tr>
<tr>
<td>91 ton C/ha</td>
<td>20 year rotation time</td>
<td>Indonesia</td>
<td>Murdiyarso 2002</td>
</tr>
<tr>
<td>36 ton C/ha</td>
<td></td>
<td>Malaysia</td>
<td>Henson 2003</td>
</tr>
<tr>
<td>30 ton C/ha</td>
<td>51 oil palm plantations taken from several studies</td>
<td>Global</td>
<td>Germer and Sauerborn 2008</td>
</tr>
</tbody>
</table>

**Comment:** Location

**Source:**
- Kongsager et al. 2012
- Palm et al. 2005
- Murdiyarso 2002
- Henson 2003
- Germer and Sauerborn 2008
Agroforestry in General

- Carbon sequestration potential greater than crop or pasture systems
  

- Lower GHG emissions compared to cropping systems
  

- Agroforestry systems can regain 35% of the carbon stock and store soil carbon at a rate of 80–100% that of forest, compared to 12% and 50 % respectively on crop or pastureland
  
  Palm et al. 2004; Watson et al. 2000

- However, systems vary considerably and sequestration potential depends on practices used
  
  Albrecht and Kandji 2003; Current et al. 1995; Mutuo et al. 2005

Main source: Anderson and Zerriffi 2012
REDD+

- REDD+ is a payment scheme
- Negotiations are in progress, but the guidelines will most likely not be stricter than the ones in the Kyoto P. (CDM)
  - Crown cover: 10-30%
  - Area: 0.5-1.0 ha
  - Height: 2-5 m
- Scenarios
  - From agriculture to rubber plantation = reforestation/afforestation
  - From forest to rubber plantation = forest degradation
- Rubber vs Oil Palm

Source: Personal communication: Peter Aarup Iversen, UN-REDD Technical Specialist, UNDP Cambodia
Examples of rubber projects

- Promoting Sustainable Development through Natural Rubber Tree Plantations in Guatemala
- VCS (Voluntary Carbon Standard) – applying the A/R CDM methodology
- 3,900,439 tCO$_2$ over 42 years through the reforestation of 2,366.16 ha with rubber trees.
- Establish in degraded and degrading lands
- Traditional use: cattle grazing
- Smallholders on privat land
- Timber will be certified under the Forest Stewardship Council (FSC)
- Carbon credit revenue is spend on project activities
Examples of a… (cont)

- Baseline study to show eligibility (not forested on December 31st 1989 + no forest in the last 22 years)
- Additionality: compared to Business As Usual and four other alternative land use scenarios
- Measurements: Aboveground (Diameter at breast height) + Belowground (ratio of aboveground)
- Leakage: Grazing animals were transferred to identified grasslands or slaughtered
Examples of a… (cont)

• The productive life is approximately 40 years
• Productivity declines after ca 20 years
• Rubber will be extracted starting in year six continuing for a minimum of 30 years
• Harvested for timber (FSC)
• Plantation will be replanted
• Environmental Impacts
• Social impacts

Source: http://www.rainforest-alliance.org/climate/projects/pica-project

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Examples of a… (cont)

Colombia (78,160 tCO$_2$)
- Establishing 4,109 ha of rubber plantations on cattle pastures

Lao People's Democratic Republic (40,672 tCO$_2$)
- Establishing 1,046 ha of rubber plantations on degraded and abandoned grasslands
- Main aims are:
  - poverty alleviation and wealth creation in rural areas
  - communities empowerment through active participation in all stages of the project
  - improvement of basic infrastructure for rural communities
- Technical and investment barrier for small-farmers

Source: http://cdm.unfccc.int/Projects/Validation

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Summary

Are rubber plantations a good idea in regard to climate change mitigation?

• Suitable location in regard to sequestration
• Level of intensity
• Established on land with modest carbon content, such as degraded forest or agricultural land

A good idea in regard to Sustainable Development?

• Impact on Local livelihood and Biodiversity
References


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References (cont)

Thank you for your attention…

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Kade, Ghana - Photo: J. Napier 2011

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